MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

ETN4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(All sections/Groups)

11 MARCH 2016
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Answer **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1 (25 marks)

(a) Define the following terms:

(i) critical angle. [2 marks]
(ii) acceptance angle. [2 marks]

(b) An optical fiber with a radius of $3\mu m$ and a refractive-index of the core and cladding being 1.46 and 1.457 respectively. If the fiber is illuminated by a ray of $1.55\mu m$ light, determine:

(i) the normalised frequency (V). [2 marks]
(ii) the numerical aperture (NA). [2 marks]
(iii) the cut-off wavelength. [2 marks]

(c) A step index fiber with a core refractive index of 1.5 has a relative index difference of 1.3% and a core diameter of $50\mu m$. The fiber has a loss of 0.25 dB/km at a wavelength of 1550 nm.

(i) Estimate the number of guided modes propagating in the fiber when the transmitted light has a wavelength of $1.55\mu m$. [3 marks]

(ii) Consider the same fiber now having a graded index profile. What would you expect in terms of guided modes propagating in the fiber? Explain why. [2 marks]

(iii) A transmission at 1550 nm wavelength was launched with a power of 0.5 dBm. What is the received power at the end of the 115 km of fiber? [2 marks]

(d) Chromatic dispersion can cause poor quality transmission in optical fiber communication systems.

(i) Elaborate on material dispersion and waveguide dispersion. [4 marks]

(ii) A step-index optical fiber has a chromatic dispersion coefficient, D of 16 ps/ nm.km. Calculate the dispersion of a light pulse, which originates from a laser with linewidth of 0.01 nm and propagates a total distance of 134 km. [4 marks]

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Question 2 (25 marks)

(a) Table 1 shows the characteristics of two types of optical sources.

Table 1

Optical source type	Optical source characteristics
Optical source A	- Incoherent source - Less complex drive circuitry compared to optical source B
Optical source B	- Coherent source - Optical bandwidth less than 1 nm

(i) Name the two types of optical sources in Table 1. [2 marks]

(ii) Which of these two types of optical sources are more suitable to be used in a wide bandwidth optical communication system? Give THREE (3) reasons to support your answer. [5 marks]

(iii) Describe the process of how light is emitted in optical source A. You must include relevant energy state diagrams (initial and final state) in your answer. [4 marks]

(b) A photodetector is used at the front end of an optical receiver. Briefly describe how a photodetector works. [2 marks]

(c) On average, a certain photodiode generates one electron-hole pair per three incident photons at a wavelength of 0.8 μm. Assume that all the electrons are collected. The received optical power of the photodiode is 0.1 μW.

(i) What is the quantum efficiency and responsivity of the photodiode? [4 marks]

(ii) Calculate the maximum possible bandgap energy (in eV) of the photodiode. [3 marks]

(iii) Calculate the mean output photocurrent. [3 marks]

(iv) Calculate the output photocurrent if the photodiode is an avalanche photodiode (APD) with a multiplication factor of 15. [2 marks]

Continued ....

Question 3 (25 marks)

(a) Two categories of optical amplifiers are semiconductor laser amplifiers and doped fiber amplifiers.

(i) Describe TWO (2) disadvantages of doped fiber amplifiers. [4 marks]

(ii) For linear applications using semiconductor laser amplifiers, travelling wave amplifiers are used more widely than Fabry-Perot amplifiers. Give TWO (2) reasons for this. [4 marks]

(b) An Erbium doped fiber amplifier (EDFA) is being pumped at 980 nm with a 30 mW pump power. The gain at 1550 nm is 20 dB. Calculate:

(i) the maximum input power. [2 marks]

(ii) the maximum output power. [2 marks]

(c) Two types of digital modulation scheme are non-return-to-zero (NRZ) and return-to-zero (RZ).

(i) Describe these two modulation schemes. [4 marks]

(ii) Which digital modulation scheme is mainly used in long distance submarine systems? Give ONE (1) reason for this. [3 marks]

(iii) Why does conventional NRZ and RZ system use low intensity pulses? [2 marks]

(iv) A light signal is transmitted in the form of optical intensity with the bit sequence '10110' and is modulated using a modulator. Illustrate the modulated signals when implementing ON-OFF keying intensity modulation using NRZ and RZ codes. [4 marks]

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Question 4 (25 marks)

As an optical communications engineer, you have been assigned to design an optical link between two cities 110 km apart. The requirements are summarized as follows:

Table Q4.1 Requirements

Bit-rate	2.5 Gb/s
Length	110 km
Minimum receiver power	-26 dBm
Modulation format	RZ

You may consider the following optical sources and fiber choices (Table Q4.2 and Q4.3) in your design.

Table Q4.2 Optical Source

	DFB Laser	**DFB Laser**
Wavelength (nm)	1300	1550
Maximum Power (dBm)	-3	0
Spectral width (nm)	0.1	0.1
Transmitter rise-time (ns)	0.05	0.05

Table Q4.3 Optical Fiber

	Single Mode Fiber	**Multimode Fiber**
Attenuation at 1300 nm (dB/km)	0.8	0.9
Attenuation at 1550 nm (dB/km)	0.25	0.25
Intermodal Dispersion Coefficient (ps/m)	0	10
Dispersion Coefficient at 1300 nm (ps/km.nm)	0	0
Dispersion Coefficient at 1550 nm (ps/km.nm)	16.0	16.0

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Question 4 (continued)

(a) Based on the information provided in Tables Q4.2 and Q4.3, propose a suitable combination of optical source and optical fiber based on the requirements mentioned in Table Q4.1 using the following:

(i) optical power budget [10 marks]

(ii) bandwidth budget [10 marks]

(b) Suggest and elaborate, with the aid of a suitable diagram, a suitable solution to reduce the effect of intermodal dispersion in step-index multimode fiber.

[5 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

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